THE EFFECT OF LEVEL OF SERVICE ON INTERCITY BUS RIDERSHIP IN MINNESOTA

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INTRODUCTION

An interesting question to transportation planners and policy makers is that concerned with estimating the number of additional bus trips that might be generated by increasing the level of service. Since the level of service is a policy variable that can be changed by either the bus company or by a local government (especially one that subsidizes the intercity public transportation), these policy makers might be interested to know the expected bus flow generated by increasing the level of service on various bus routes. Such an estimation could identify bus routes for experimentation with a high probability of success. If subsidizing intercity public transportation is considered (by a state or a local government), two additional types of information may be useful for the decision-making process: 1) the socio-economic profile of the additional bus riders, and 2) the number of trips for which bus services are not available. The latter may suggest the need to try additional linkages to the existing service network.

This study mainly estimated the number of bus trips generated by changing the level of service for all Twin Cities-oriented bus routes in Minnesota and delineated the socio-economic profile of the potential riders. The study looks at potential for both increased service on existing routes and new service where none existed before. The research was based on an intercity modal choice model developed by the author as part of his Ph.D. thesis.[1] The model was tested successfully in five different city-pair corridors in southeastern Minnesota and was presumed to be geographically transferable.

Two trip purposes were examined: work trips, the leading trip purpose among auto drivers and, social-recreation trips, the leading trip purpose among bus riders.

MODAL CHOICE MODEL FOR INTERCITY BUS TRANSPORTATION

As mentioned previously, the modal choice model was used to estimate the number of additional bus trips that would be generated by increasing the level of service. The model, known as the "logit model," determines the relationship between the probability of an individual's choosing a specific transportation mode and the utility from that mode, where the dependent variable is clearly dichotomous; that is, the trip-maker chooses mode A or does not choose mode A. The probability of trip-makers who responded by choosing a particular mode of transport follows the relationship presented by a sigmoid curve, known as the "logistic curve."

The general form of the logit model used in this study is written as:

$$P_i = \frac{e^{f(x_j)}}{1+e^{f(x_j)}}$$

where, P_i is the probability that an individual will choose mode i, and $f(x_j)$ is a combination of variables (x_j) affecting modal choice. The best combination of explanatory variables were developed from survey data from southeastern Minnesota by two least squares methods: a linear stepwise regression analysis and a non-linear routine.[2]

In order to undertake these analyses, the data were classified into groups and the ratio, number of bus trips/number of car trips (n_b/n_c), was calculated for each group. The coefficients of x_j in $f(x_j)$ were estimated using the least squares approach to be as follows:

For social-recreation trips

$$f(x_j) = \log_e(n_b/n_c) = 8.2357 + 0.3927(x_1) - 0.4787(x_2) + 0.0151(x_2)^2 - 0.4680(x_3) + 0.0053(x_3)^2 + 0.0507(x_4)$$

for work trips

$$f(x_j) = \log_e(n_b/n_c) = 1.8248 - 1.1937(x_1) - 0.3898(x_2) + 0.0123(x_2)^2 -$$
$$-0.2261(x_3) + 0.0027(x_3)^2 + 0.1262(x_4) + 0.0686(x_5)$$

where,

x_1 - trip purpose (1 where trip purpose is work or social-recreational; 0 otherwise)

x_2 - income of trip maker

x_3 - age of trip maker

x_4 - level of service

x_5 - travel cost difference (based on total trip expenses).

Level of service is a combination of availability and frequency of bus service and is represented by an index which was derived through a manipulation of connectivity matrices. A change in the bus service schedule will result in a change in the index. The effect of such a change on bus ridership in a given service route was measured through the presented form of the logit model.

DATA SOURCES

The data for calibrating the social-recreation and work trips models were collected from two sources:

1) A bus survey conducted by the author in which 2,000 bus riders were systematically sampled in the Twin Cities, Rochester, and Mankato terminals. The returns (1,100) represent 13 percent of the weekly bus flow in southeastern Minnesota.

2) The Minnesota Highway Department's Screenline Origin-Destination Survey,[3] from which all the external trips departing from southeastern Minnesota or heading toward the region were recorded.* The survey provided information about the socio-economic characteristics of the auto drivers, their trip purpose, origin, and destination. The information was used with the bus survey information to calibrate the modal choice model, after both samples were adjusted to the same representation level.

In order to include in the investigation bus routes outside the southeastern part of the state, all the external trips, sampled in the 34 stations of the screenline survey (Figure 1), were recorded (4,320 trips). The total number of intercity auto trips was derived from the Twin Cities' External Origin-Destination Survey[4] in which 58,245 trips were sampled in 31 stations (Figure 1). This sample represents 46.9 percent of the 15-hour traffic interview period.

THE INTERCITY BUS MARKET POTENTIAL

The market for intercity bus service is small in relation to the total number of trips made by all modes of transportation. Bus travel has undergone a relative decrease since World War II, but buses still transport many more individuals than do either railroads or airplanes.

The market is mainly composed of people younger than 30 and older than 50 years of age. A survey in southeastern Minnesota[5] indicated

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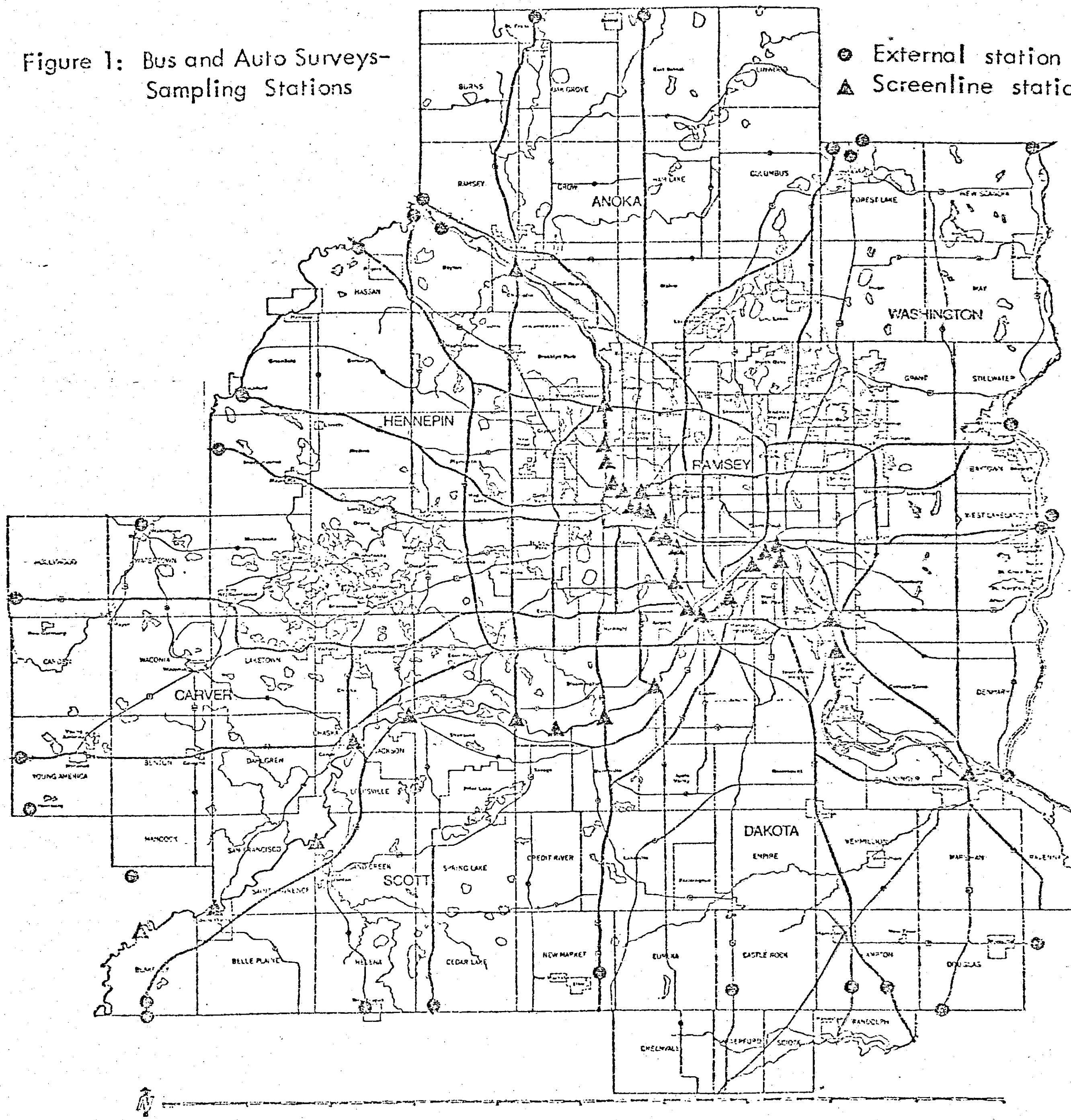
* I gratefully acknowledge the assistance of Steven Weston and Donald Lipinski, Department of Geography, University of Minnesota, in recording the auto survey data.

Figure 1: Bus and Auto Surveys-
Sampling Stations

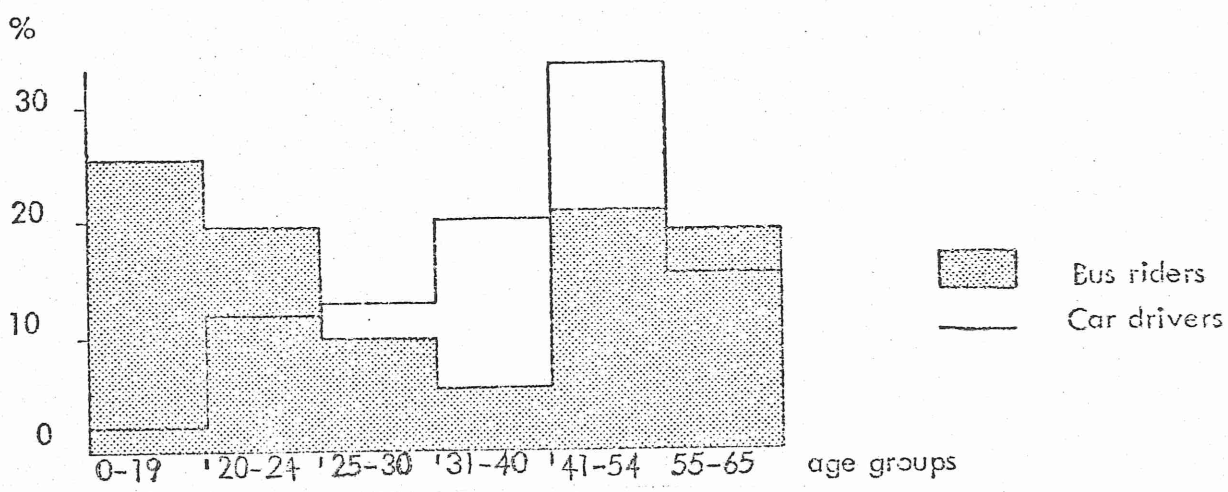


that over 84 percent of the bus riders fell into these categories and only 16 percent were passengers between 30 and 50 years old. The private car market reflects the opposite situation:[6] the middle-aged group included over 55 percent of the total riders; 25 percent were people under 30 and 20 percent were people over 50 (Figure 2A).

With regard to household income of bus and car travelers, it was found that 79 percent of the bus market is made up of people earning less than $12,500 per year, compared with 51 percent of car drivers with the same level of income (Figure 2B). In the low income levels, 33 percent of the bus riders were persons with annual income of $5,000 and less, while only 9 percent of such people were found among car drivers. It is obvious from the cumulative percentages that low-income people tend to use the bus more than the car but it is noteworthy that bus ridership is relatively higher among people making $20,000 and more.

In theory, the potential of the intercity bus market comprises all the intercity travelers by all modes. Since the intrastate air and rail service in Minnesota is marginal, only the auto market is considered competitive with the bus. Thus, the intercity auto trips were classified by bus route; that is, the appropriate bus route (or routes when transfers are needed) was attached to the auto trip as if the trip would have been made by bus. The total number of auto trips assigned to each bus route included auto trips to destinations not being served by bus. Therefore, the number of such auto trips was subtracted from the total number of trips assigned to each bus route in order to derive the projected potential for each route. The results for all Twin Cities-oriented bus routes are presented in Figure 3.

A. Bus riders and car drivers distribution by age.



B. Bus riders and car drivers distribution by income.

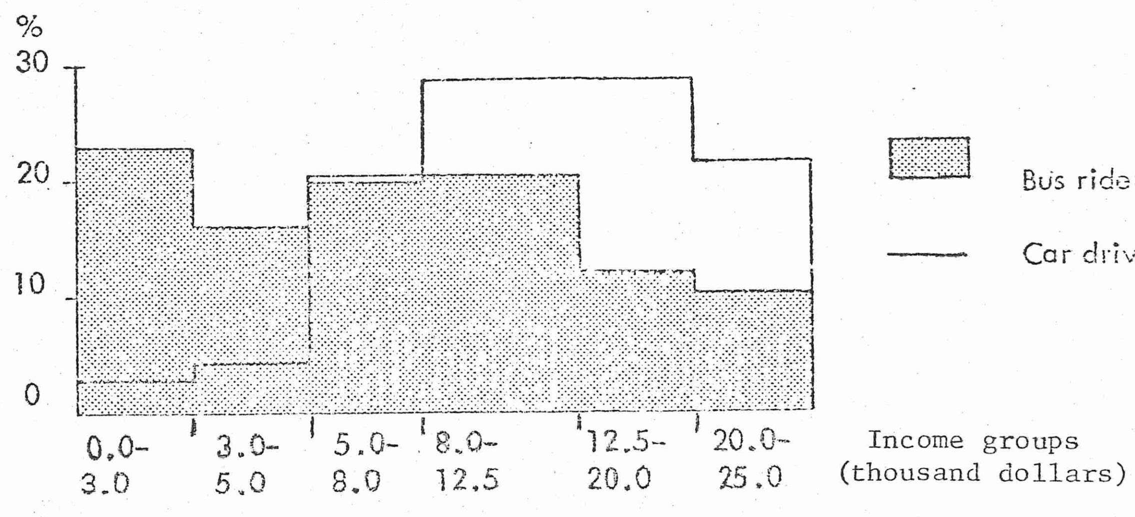


Figure 2: Socio-economic profiles of bus riders and car drivers.
Source: Bus and Auto Screenline Surveys.

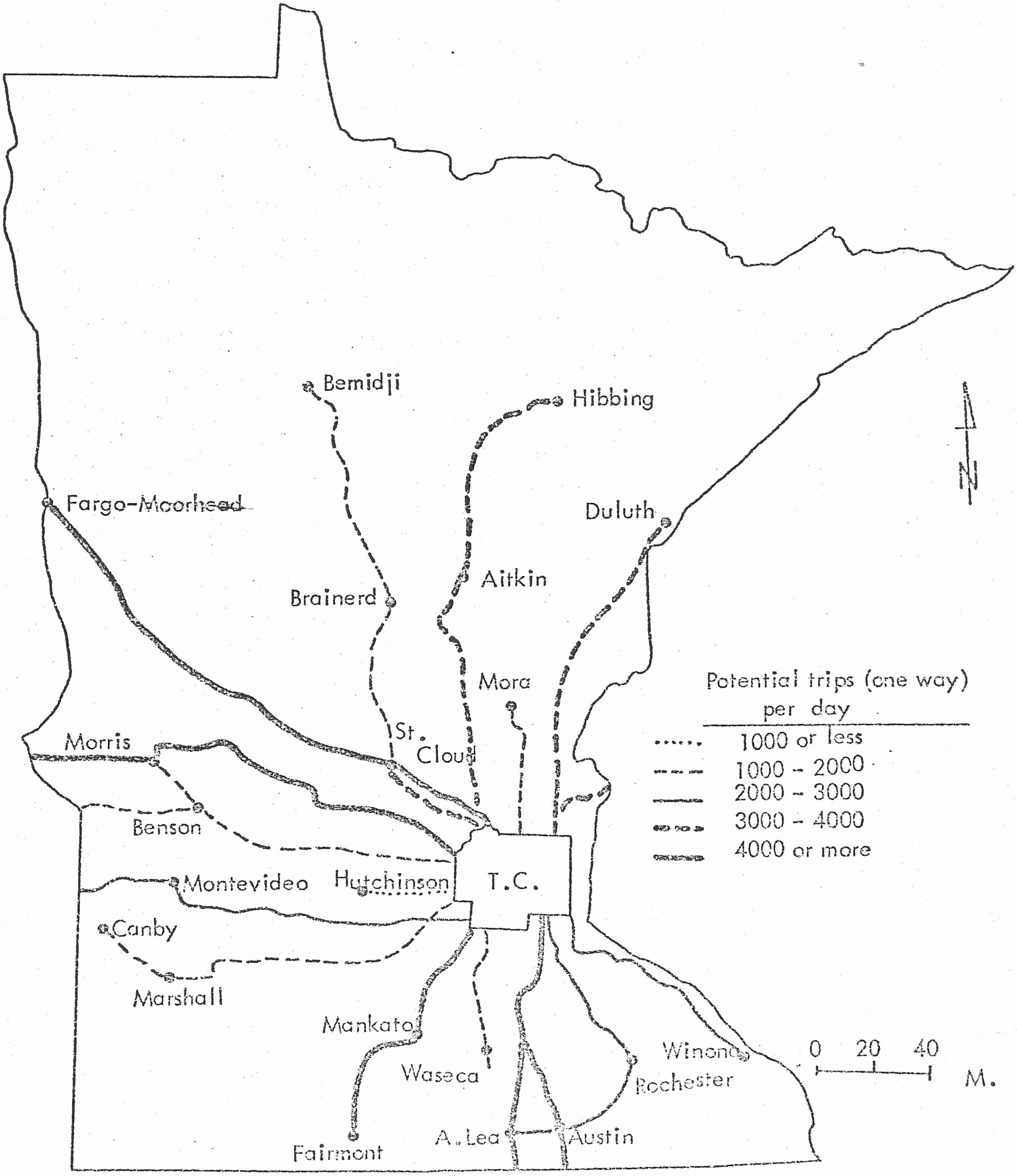


Figure 3: Potential trips for Twin Cities-oriented bus routes.

The bus rider potential on each route has a different socio-economic profile and, therefore, variations in the travelers' preferences, with regard to the service attributes, were expected to be found among the routes. Moreover, the distribution of trip purpose and the level of service varies from route to route. Thus, a correlation between the route potential and the flow generated by varying the route service frequently was not necessarily expected.

BUS FLOW GENERATED BY VARYING THE ROUTE LEVEL OF SERVICE

The generated bus flow was estimated by re-running the modal choice model with new values of level of service based on auto trips only. In this way it was possible to estimate the number of car drivers likely to switch from auto to bus after the level of service increased. The estimation of generated flow was possible in this study only for Twin Cities-oriented routes (Figure 4) because the data concerning car drivers were available only for Twin Cities-oriented auto trips.

From a planning point of view it was assumed that increasing a route level of service by one bus per day is economically defensible only if the number of generated trips is at least equal to the route annual average loading factor. This assumption implies that the annual average profit from operating a bus on the route will be maintained. Table 1 presents the annual average loading factors in the selected routes: i.e., the number of additional bus riders required for increasing the route level of service by one bus or more per day.

The number of additional trips needed for justifying an additional bus included trips for all purposes. Since models for only social-recreation and work trip purposes were calibrated, it was necessary to find the number of additional trips for these two purposes in order to compare it with the estimated number of generated trips. This was done by using the relative frequency distribution of trips by trip purpose for each route. For those routes not included in the bus survey, the average distribution of trip purpose was used (Table 2).

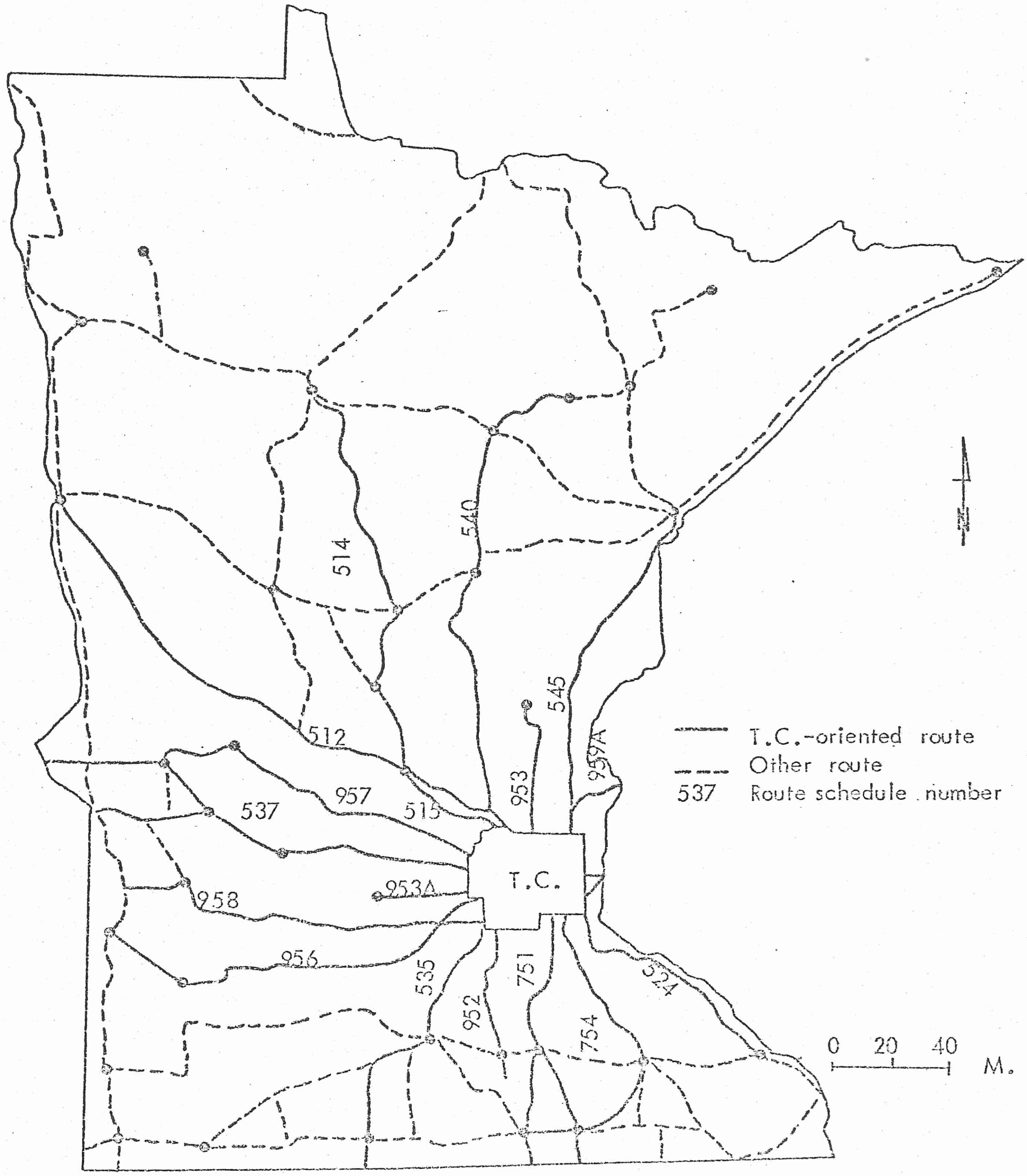


Figure 4: The 1975 bus transportation network in Minnesota
Source: Russell's Official National Motor Coach Guide, March 1975.

Table 1 : Annual Average Loading Factors for Twin Cities-Oriented Bus Routes.

Route schedule number	Origin-Destination	Loading Factor* (in percent)	Number of required trips
512	TC-Fargo-Moorhead	0.92	36
515	TC-St. Cloud	0.89	35
956	TC-Marshall	0.47	19**
959A	TC-Webster,Wi.	0.47	19**
953	TC-Mora	0.47	19**
957	TC-Morris	0.41	16
952	TC-Waseca	0.43	17
754	TC-Rochester	0.66	26
751	TC-Albert Lea	0.71	28
545	TC-Duluth	0.94	37
540	TC-Hibbing	0.41	16
514	TC-Bemidji	0.56	22
535	TC-Mankato	0.58	23
524	TC-Winona	0.61	24
537	TC-Willmar	0.47	19**
958	TC-Montevideo	0.47	19**
953A	TC-Hutchinson	0.47	19**

* Based on average of 39 passengers per bus.

** Based on national average since no other information was available.

Table 2: Trip Purpose Distribution of Intercity Bus Riders

Trip Purpose	Relative Frequency (%)
Social-Recreation	52.2
Medical	7.2
Work	3.9
Personal Business	6.2
School	9.4
Shopping	5.8
Other	14.8

Source: Bus survey conducted in southeastern Minnesota by the author.

The trip-purpose distribution was used in conjunction with the number of required trips shown in Table 1, and the number of additional social-recreation and work trips was calculated accordingly (Table 3).

When the elasticity of bus ridership with regard to level of service was calculated, it was found that people traveling to work are less sensitive to changes in level of service than people traveling for social-recreation purposes. Thus, a smaller number of generated work trips was expected to be found. The estimated number of additional bus trips (Table 4) resulting from a second run of the model was adjusted to represent the number of daily additional trips by using the representation level of the sample in each route.

The results (Table 4) showed that in eight corridors the total number of car drivers likely to switch from auto to bus was higher than their route annual average loading factor. The routes in Figure 5 have the

Table 3 : Number of Additional Social-Recreation and Work Trips Required for Justifying an Additional Bus, by Route.

Route schedule number	Origin-Destination	Soc.-Rec. trips	Work trips	Total trips
512	TC-Fargo-Moorhead	19	2.0	21
515	TC-St. Cloud	18	1.3	19
956	TC-Marshall	10	0.7	11
959A	TC-Webster, WI.	10	0.7	11
953	TC-Mora	10	0.7	11
957	TC-Morris	9	0.6	10
952	TC-Waseca	9	0.6	10
754	TC-Rochester	11	1.3	12
751	TC-Albert Lea	15	1.1	16
545	TC-Duluth	19	1.5	21
540	TC-Hibbing	9	0.6	10
514	TC-Bemidji	11	0.9	12
535	TC-Mankato	13	0.9	14
524	TC-Winona	10	0.9	11
537	TC-Willmar	10	0.7	11
958	TC-Montevideo	10	0.7	11
953A	TC-Hutchinson	10	0.7	11

Source: bus survey by the author

Table 4 : Generated Bus Trips by Route, per day (one way).

Route schedule number	Origin-Destination	Soc.-Rec. trips	Work trips	Total trips
512	TC-Fargo-Moorhead	17	6	23
515	TC-St. Cloud	9	5	14
956	TC-Marshall	4	2	6
959A	TC-Webster, WI.	13	1	14
953	TC-Mora	7	0	7
957	TC-Morris	15	1	16
952	TC-Waseca	3	0	3
754	TC-Rochester	6	2	8
751	TC-Albert Lea	19	5	24
545	TC-Duluth	14	4	18
540	TC-Hibbing	18	1	19
514	TC-Bemidji	12	0	12
535	TC-Mankato	13	4	17
524	TC-Winona	7	1	8
537	TC-Willmar	5	0	5
958	TC-Montevideo	11	0	11
953A	TC-Hutchinson	2	0	2

Source: computation by the author.

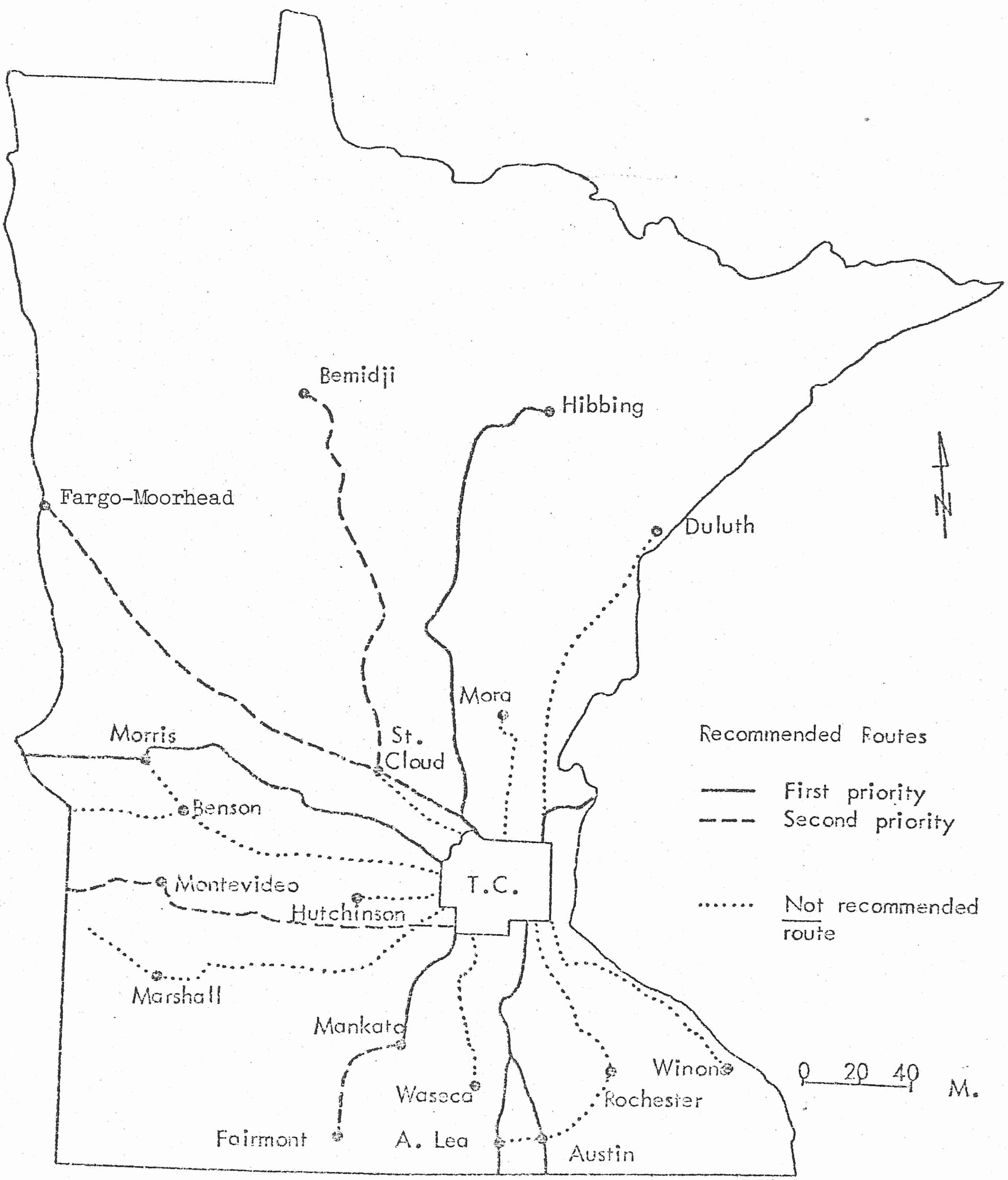


Figure 5: Recommended routes for experimentation.

highest relative probability of success. On the basis of the results, these recommended routes were then divided into two groups with different priorities for experimentation.

The first-priority group included five routes for which the socio-economic profile of the additional bus riders is presented in Table 5. The second-priority group included routes in which the estimated generated flow exactly equaled the required number of trips or, as in the case of the Twin Cities-Fargo-Moorhead route, the number of generated work trips was much higher than the required work trips. The generated work trips seemed to be less important than the generated social-recreation trips, since the individual making an intercity trip is much less likely to switch from auto to bus than the individual making the trip for social-recreation purposes.

In all the first-priority routes, relatively more young and elderly car drivers are likely to switch from auto to bus for social-recreation trips than middle-aged drivers. The same pattern was observed with regard to income where, in most cases, relatively more low- and high-income drivers would be affected by an increase in the route level of service than middle-income drivers. In any case, more young and low-income people would be affected than elderly and high-income people.

A different pattern was observed with regard to work trips. In most cases relatively more middle-aged and middle-income intercity commuters are likely to switch from auto to bus than elderly or high-income commuters. This disparity exists because the elderly are less likely to commute long distances daily, if at all. Thus, the total number of work trips generated is lower than the total number of generated social-recreation trips.

Table 5: Age and Income Distribution of Additional Bus Riders Generated by an Increased Level of Service.

A. Distribution by Age (in percent).

Route O-D	Soc.-Rec. Trips 19-34	35-54	55 +	Work Trips 19-34	35-54	55 +
TC-Albert Lea	48	13	39	55	45	00
TC-Webster, WI	37	9	54	55	25	20
TC-Morris	41	7	52	59	21	20
TC-Hibbing	27	7	66	77	13	10
TC-Mankato	67	7	26	53	30	17

B. Distribution by Income (in percent).

Route O-D	Soc.-Rec. Trips 0 - 6,000	6,000-12,500	12,500 +	Work Trips 0 - 6,000	6,000-12,500	12,500 +
TC-Albert Lea	65	22	13	27	45	28
TC-Webster, WI.	70	11	19	39	36	25
TC-Morris	63	15	22	58	29	13
TC-Hibbing	73	18	9	64	15	21
TC-Mankato	49	15	36	21	26	53

Source: Computation by the author.

In summary, 88 percent of the generated trips would be made, on the average, by young people and the elderly. With regard to income, 70 percent of the total number of additional bus riders would be on the average, people with either low or high incomes.

THE POTENTIAL FOR BUS NETWORK EXPANSION

The results of the auto survey indicated that only 14 percent of the intercity Twin Cities-oriented auto trips involve a transfer (from which only 2.3 percent involve more than one transfer) if the trip were made by bus. Therefore, it seems that improving the network's direct connectivity might not be as effective as a schedule improvement in some routes. On the other hand, some areas might have a potential which would justify the establishment of a new bus route. This potential was examined by cross-tabulating trips which departed from origins or which headed to destinations not being served by public bus transportation. Only places which generated or attracted more than 40 trips per day* were considered. These places are shown in Figure 6.

The results show that the potential is too small to justify the establishment of new Twin Cities-oriented bus routes in the state. An exception might be a commuter line from the Twin Cities to River Falls and Prescott, Wisconsin (see inset of Figure 6). Each of these places generate and attract over 600 one-way trips daily and they are not served by bus transportation. The theoretical potential of at least 1,200 one-way daily auto trips along this suggested route may justify a commuting service to the Twin Cities.

In other parts of Minnesota, the bus service network is extensive enough, the only improvements that might be economically justified concern the service frequency as discussed previously.

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* Capacity of one bus

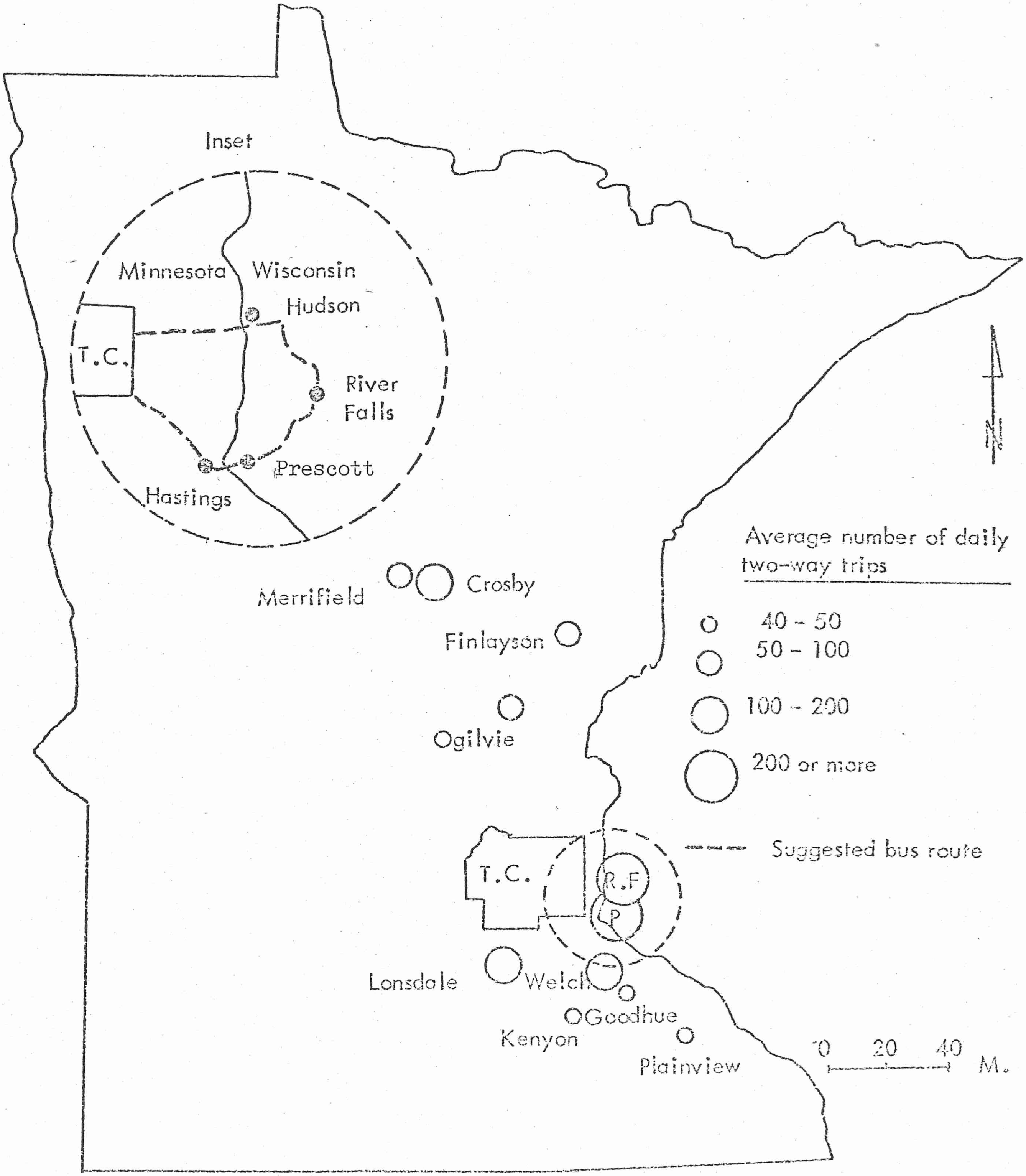

Figure 6: Potential for bus network expansion.

SUMMARY

Usually, the common practice of making projections for a particular mode on the basis of improvements involves considerable risk. This is clearly so because of the many variables involved in any generalization about mode choice. Therefore, the author avoided predicting modal choice but rather identified bus routes in which modal choice might be affected by improving the service.

The main element examined, level of service, encompassed schedule flexibility, which is considered to be an important factor in explaining mode choice,[7] although its effect has not been measured previously. The lack of schedule flexibility, for example, is considered to be one of the important explanations of the decline in intercity rail passenger service in the United States.[8] However, bus schedules can be more flexible than air or rail service schedules because buses operate with much lower passenger-capacities than airplanes or trains. The private auto, of course, has more schedule flexibility than any public mode but the increase of bus schedule flexibility might affect some segments of the travelers population enough to economically justify the change.

This point was examined in 17 bus routes in Minnesota and, according to the results, improvements in service frequency can generate enough trips to justify the improvement in certain parts of the network. In any case, an improvement of this type must be advertised before an experimental change is tried.[9]

Other places, which are not currently served by Twin Cities-oriented bus service, were examined to see whether they could support bus service. Only one new route showed the potential for being self-supporting.

FOOTNOTES

1. Eliahu Stern, "Bus Transportation as an Intra-Regional Transit Mode," Unpublished Ph.D. thesis, Department of Geography, University of Minnesota, July 1976.

2. The SPSS 6000 Version 6.0 computer program, 1975, was used.

3. Office of System Planning, Data Collection Phase, Screenline O-D Survey 1970, Minnesota Highway Department, January 1971.

4. Minnesota Highway Department, Twin City Metropolitan Area External Survey Manual 1970, January 1971.

5. This survey was done by the author in September 1975.

6. Based on the Highway Department Screenline Survey with regard to external trips. See footnote 3.

7. See for example, John R. Meyer and Mahlon R. Straszheim, Techniques of Transport Planning, Brookings Institute Transport Research Program, Washington D.C., Vol. I, 1974, Chapter 9.

8. Ibid, pp. 162-163.

9. This is expected to be necessary since the model used assumes "perfect knowledge."